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Sugie et al.

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(54) **ELECTROMAGNETICALLY-DRIVEN VALVE**

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F01L 9/04 (2006.01)

(52) **U.S. Cl.** **123/90.11**; 123/90.22; 251/129.16

(58) **Field of Classification Search** 123/90.11, 123/90.15, 90.22, 90.4, 90.23, 188.2; 251/129.16
See application file for complete search history.

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(57) **ABSTRACT**

An electromagnetically-driven valve includes intake valves that are provided in a gasoline engine and that are arranged side by side; a valve plate that connects the intake valves to each other, wherein driving force that is generated by electromagnetic force is transferred to the valve plate; and a changing mechanism that is fitted to the valve plate. The changing mechanism changes the valve drive state between the two-valve drive state, in which both of the intake valves are driven, and the one-valve drive state, in which one of the intake valves is driven and the other intake valve is stopped.

6 Claims, 8 Drawing Sheets

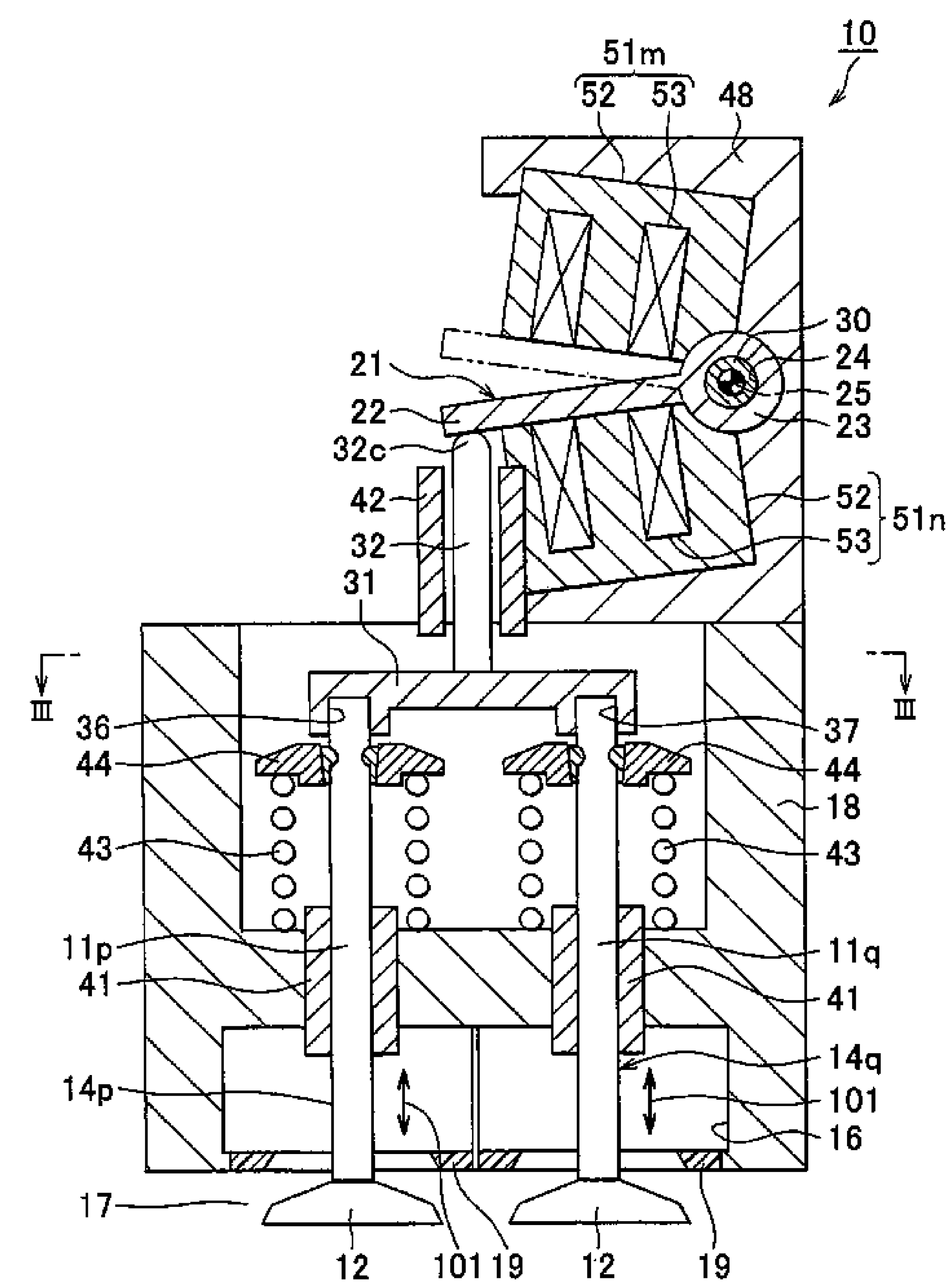
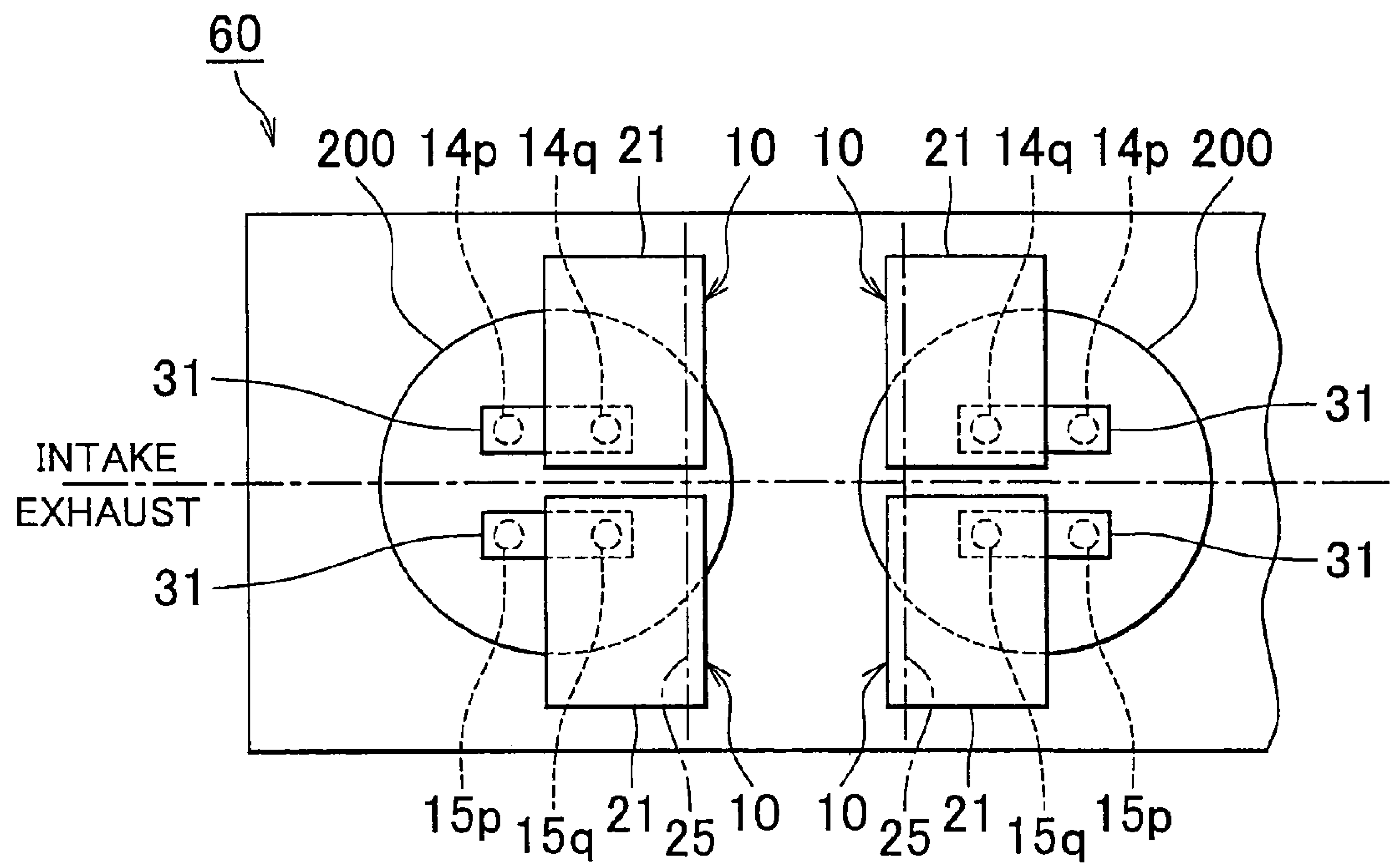


FIG. 1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200
14p
14q
21
10
10
21
14q
14p
200
31
31
INTAKE
EXHAUST
31
31
15p
15q
21
25
10
10
25
21
15q
15p

FIG. 2

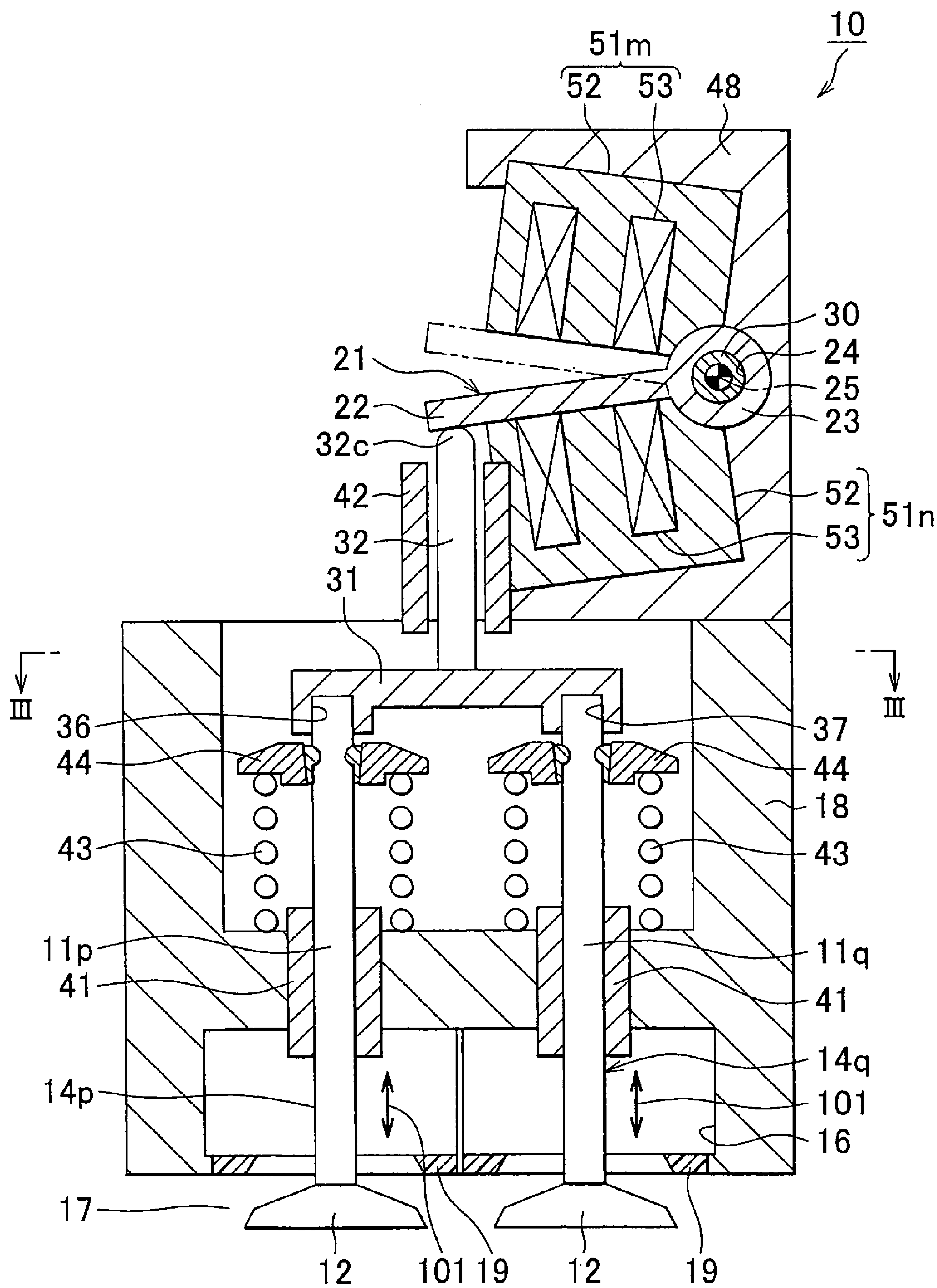

10
51m
52
53
48
30
24
25
23
21
22
32c
42
32
31
52
53
51n
III
III
36
37
44
44
18
43
43
11p
11q
41
41
14q
14p
101
16
17
12
101
19
12
19

FIG. 3

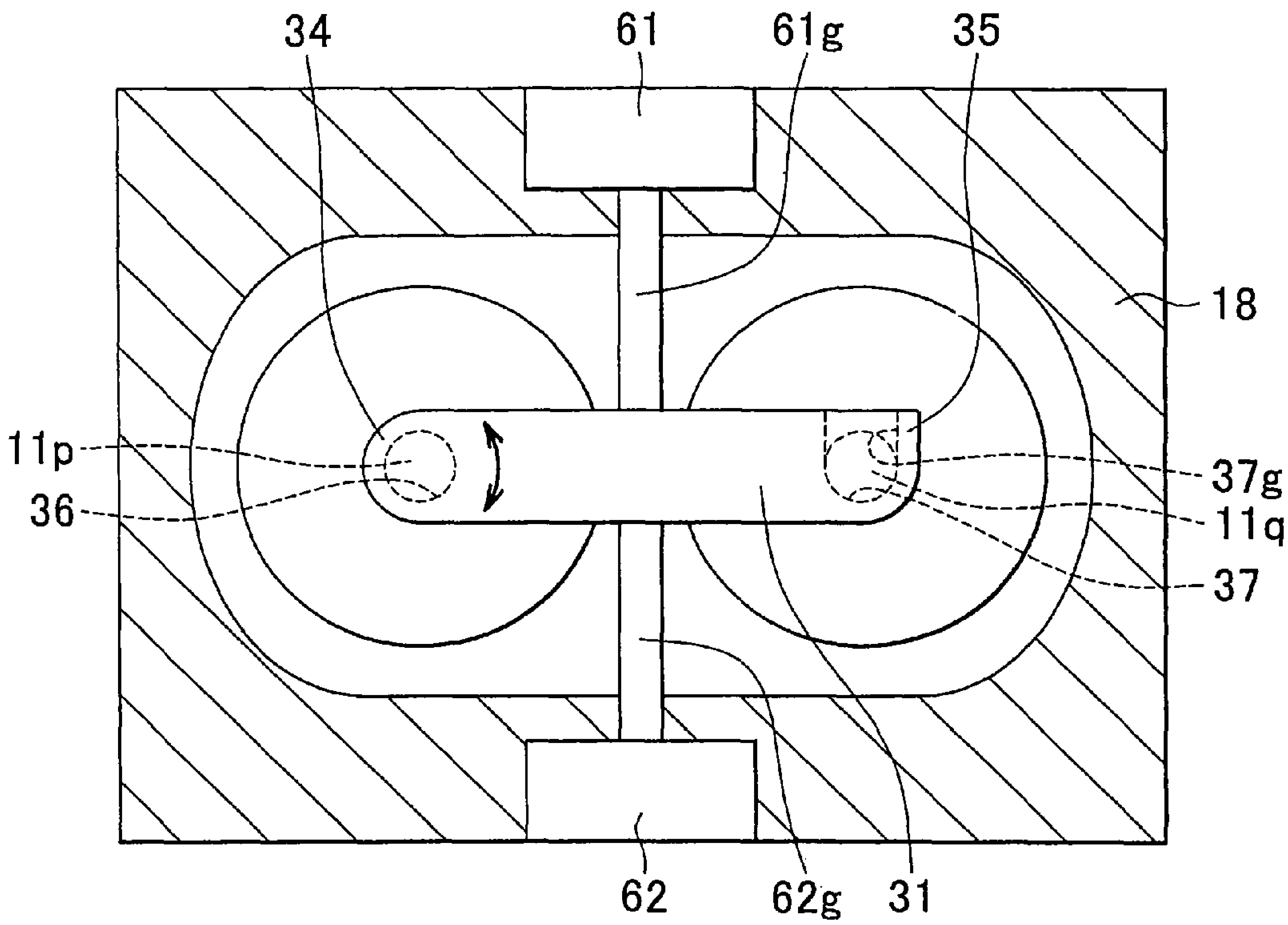

34
61
61g
35
18
11p
36
37g
11q
37
62
62g
31

FIG. 4

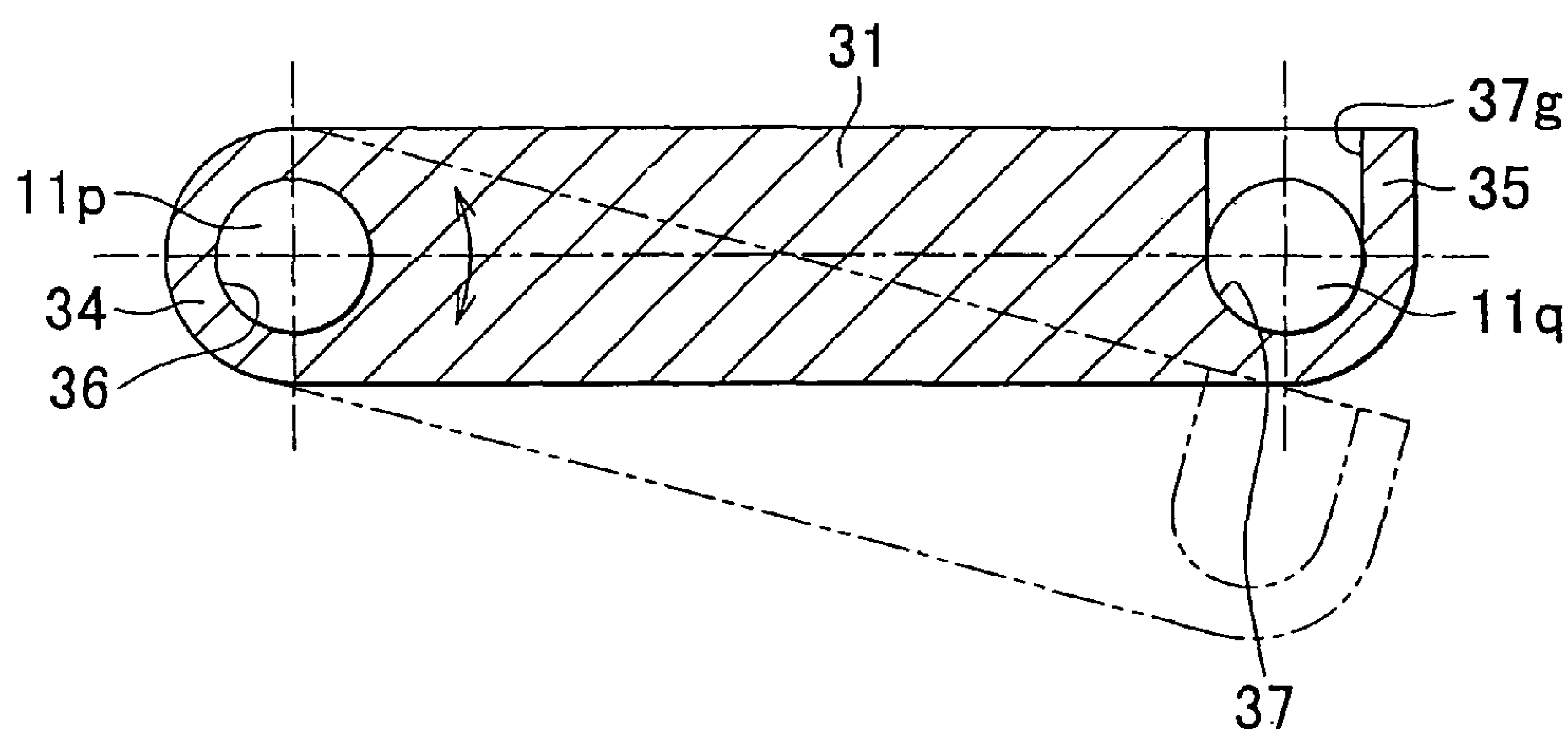

31
37g
11p
35
34
11q
36
37

FIG. 5

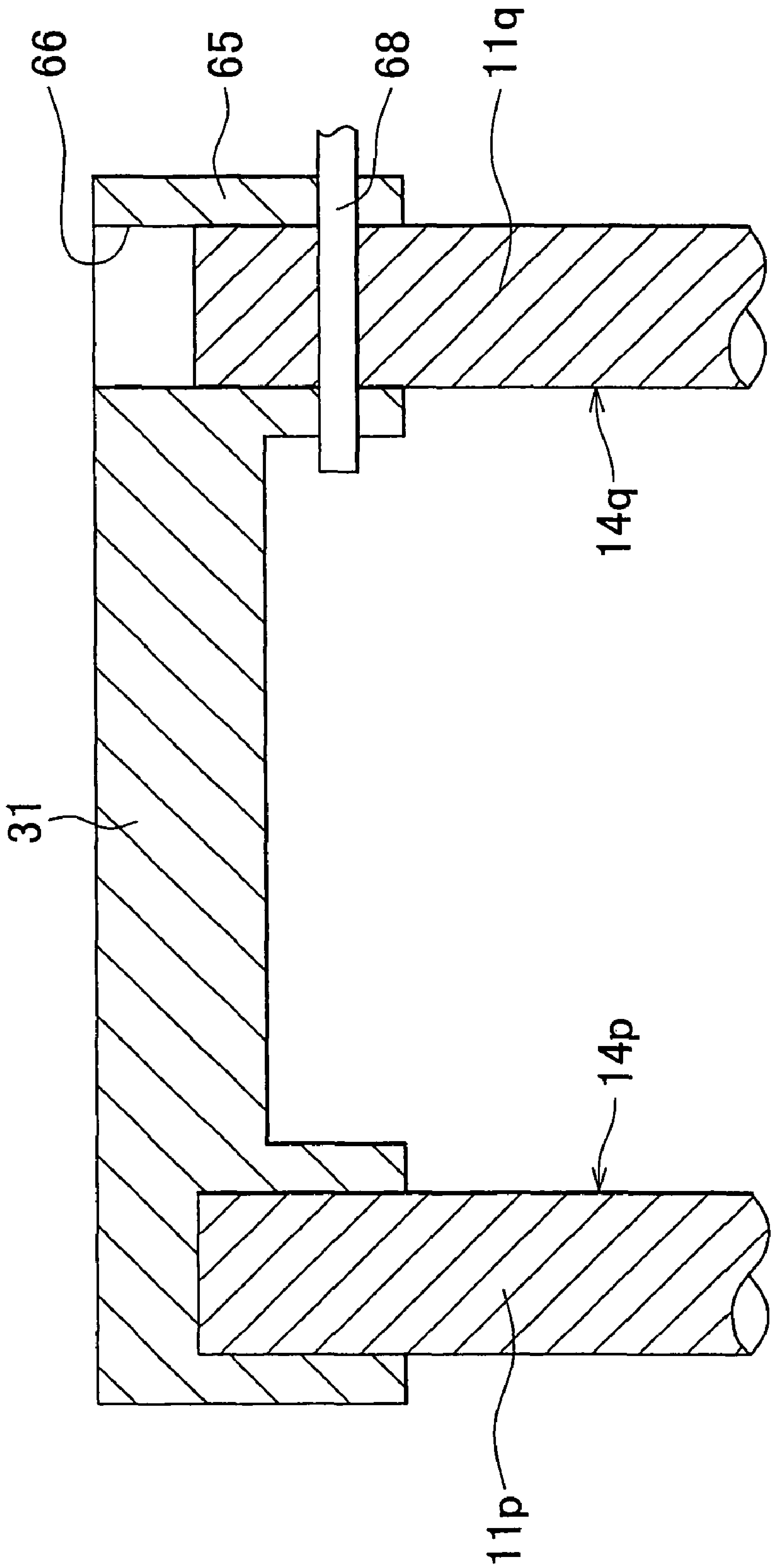


FIG. 6B

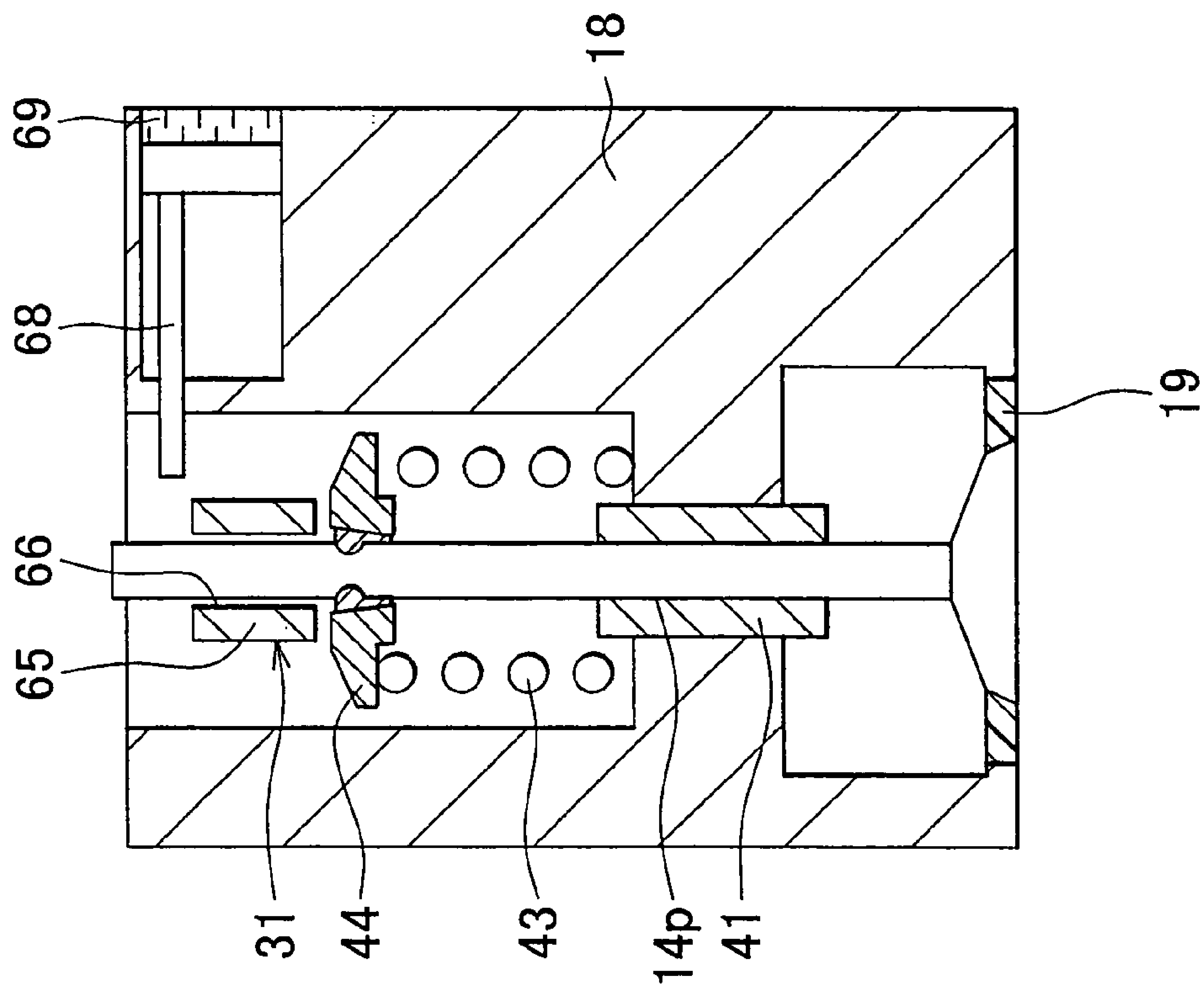


FIG. 6A

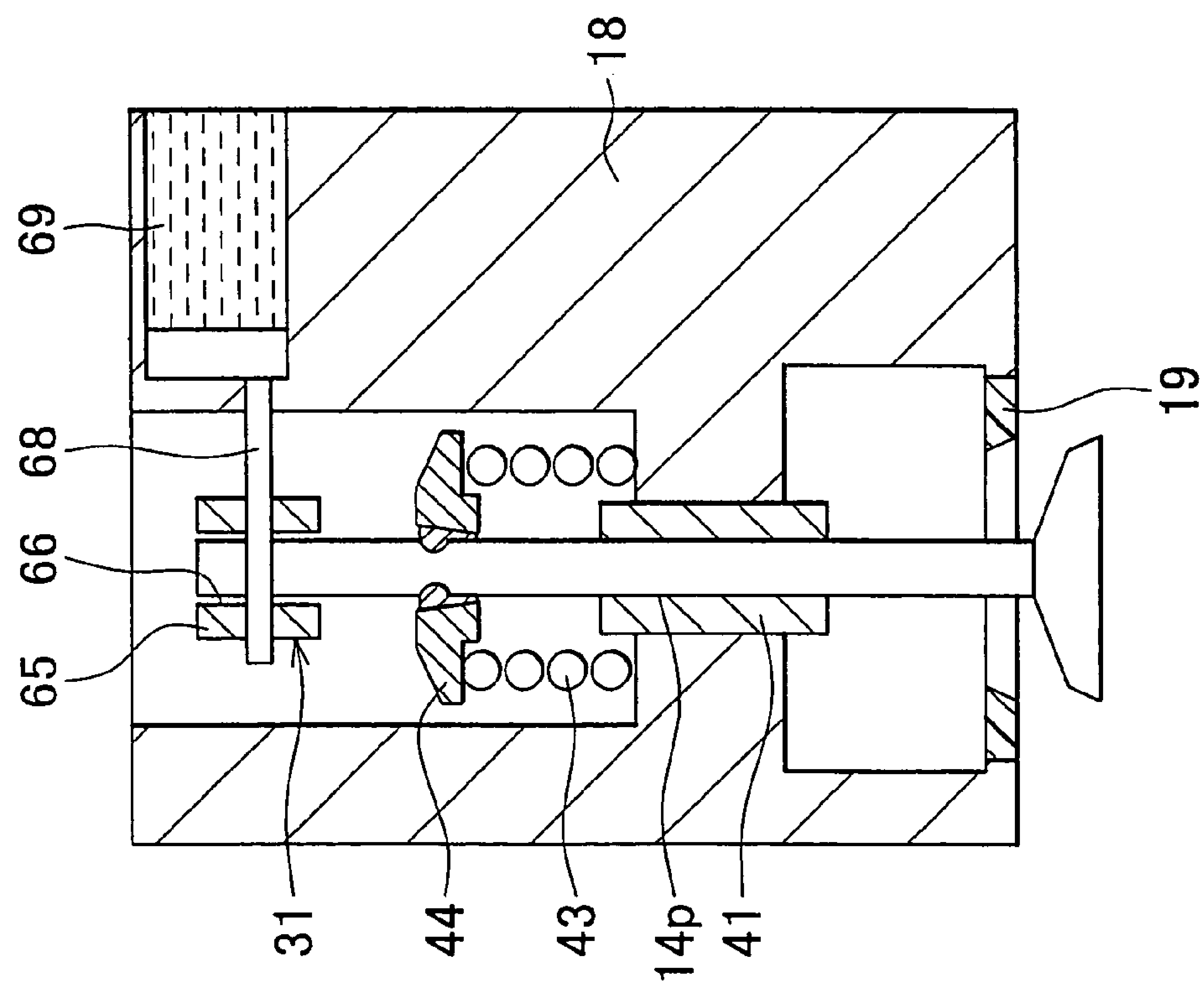


FIG. 7

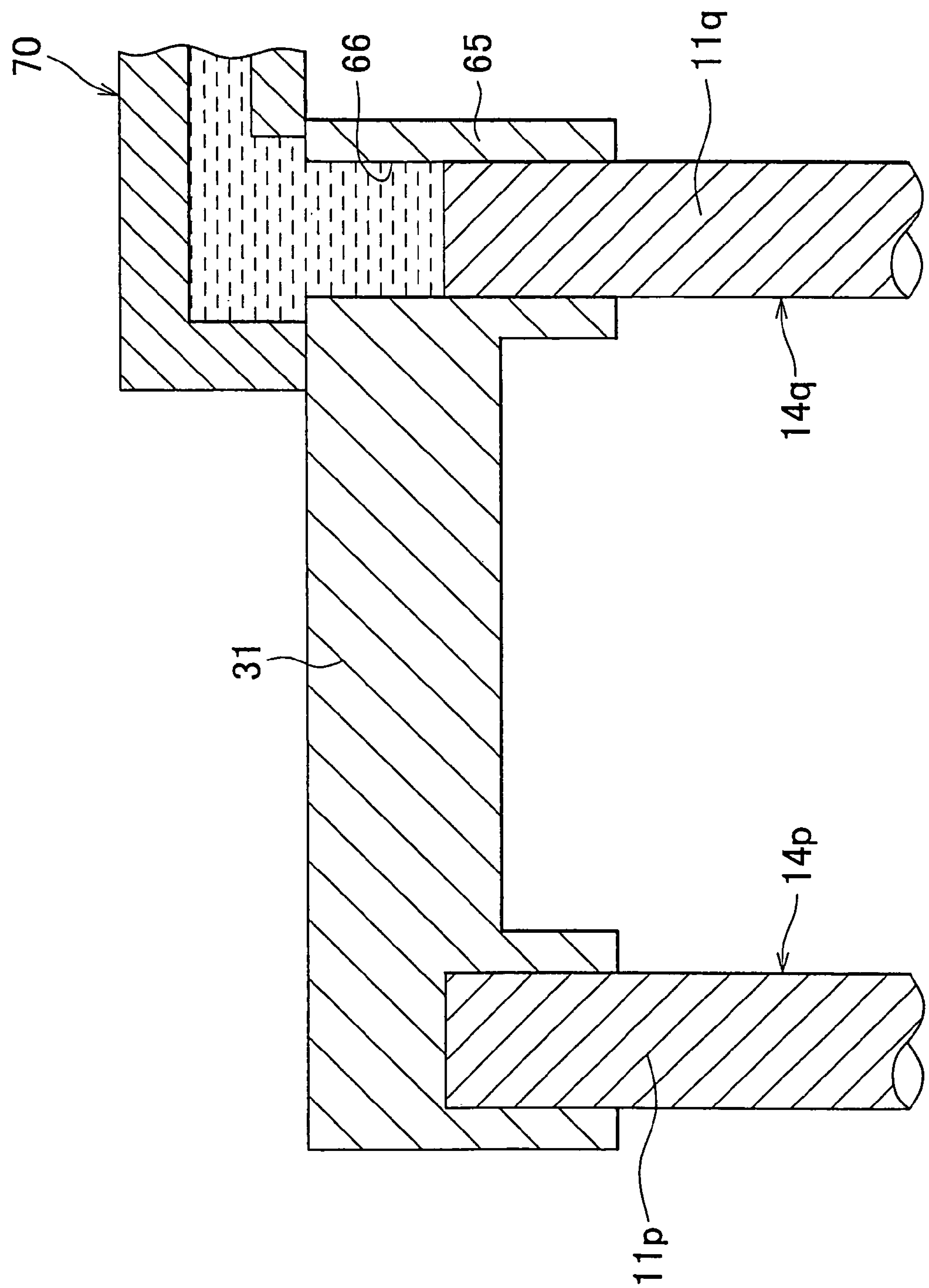


FIG. 8B

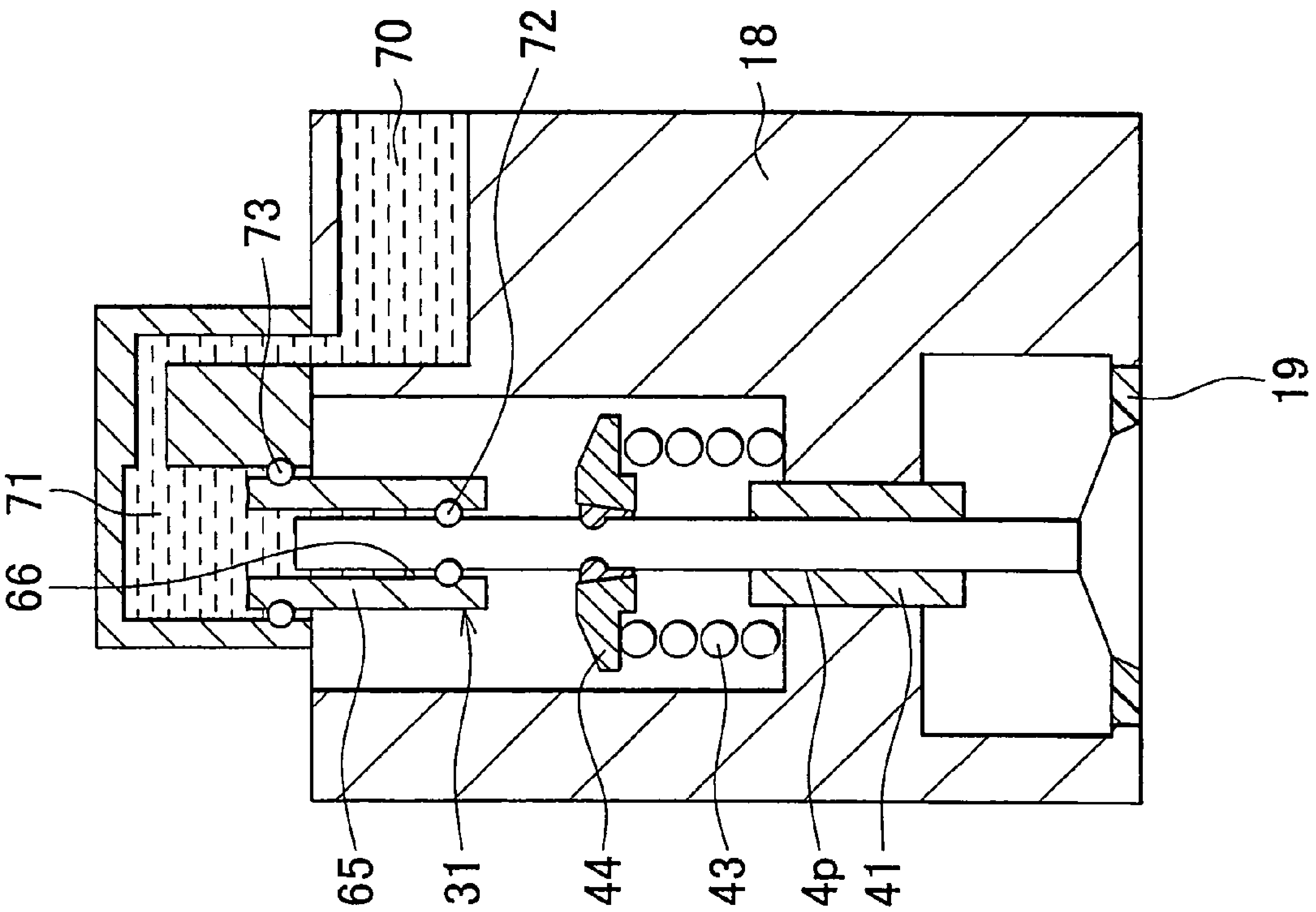

70
72
18
73
71
66
19
65
31
44
43
14p
41

FIG. 8A

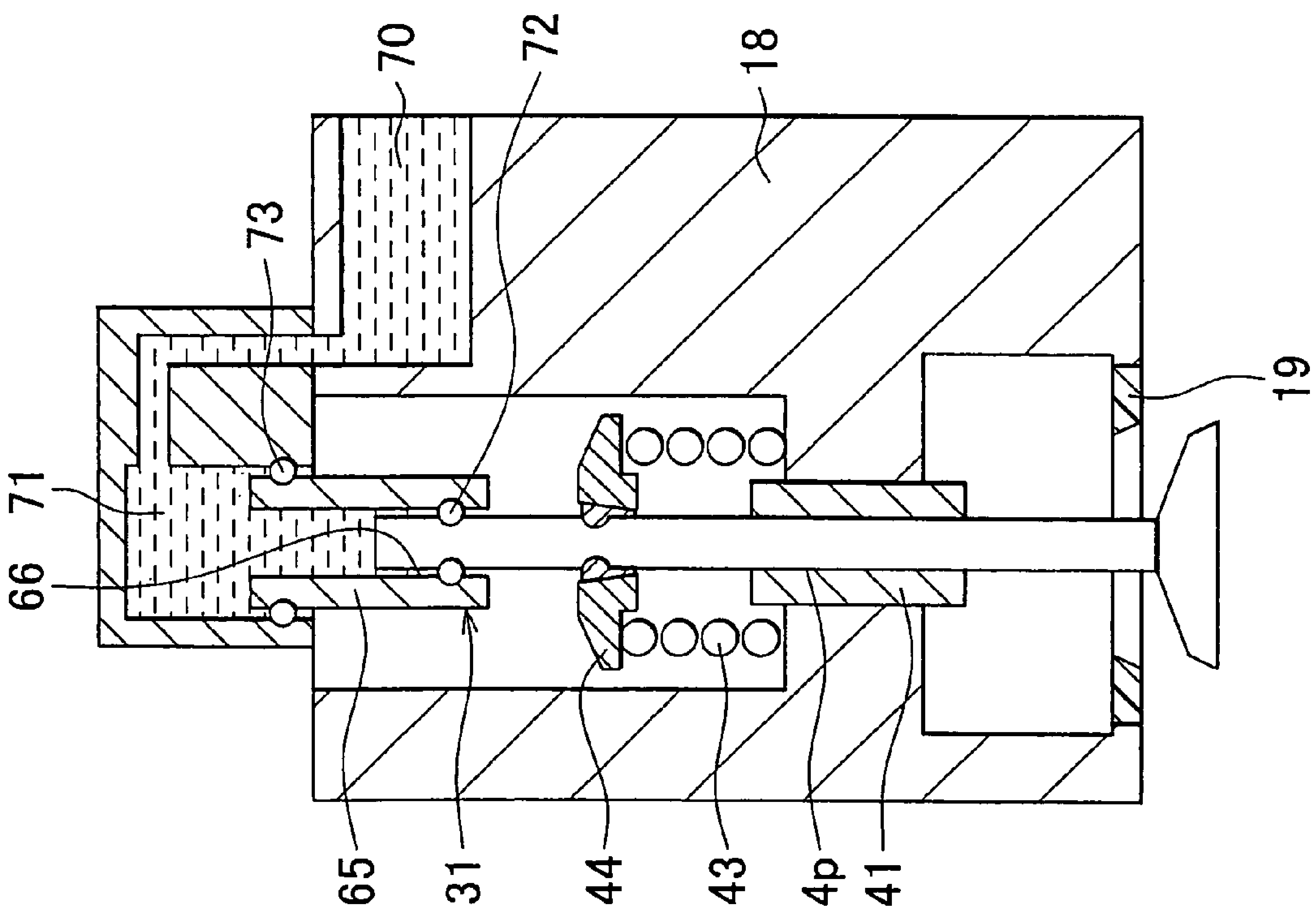
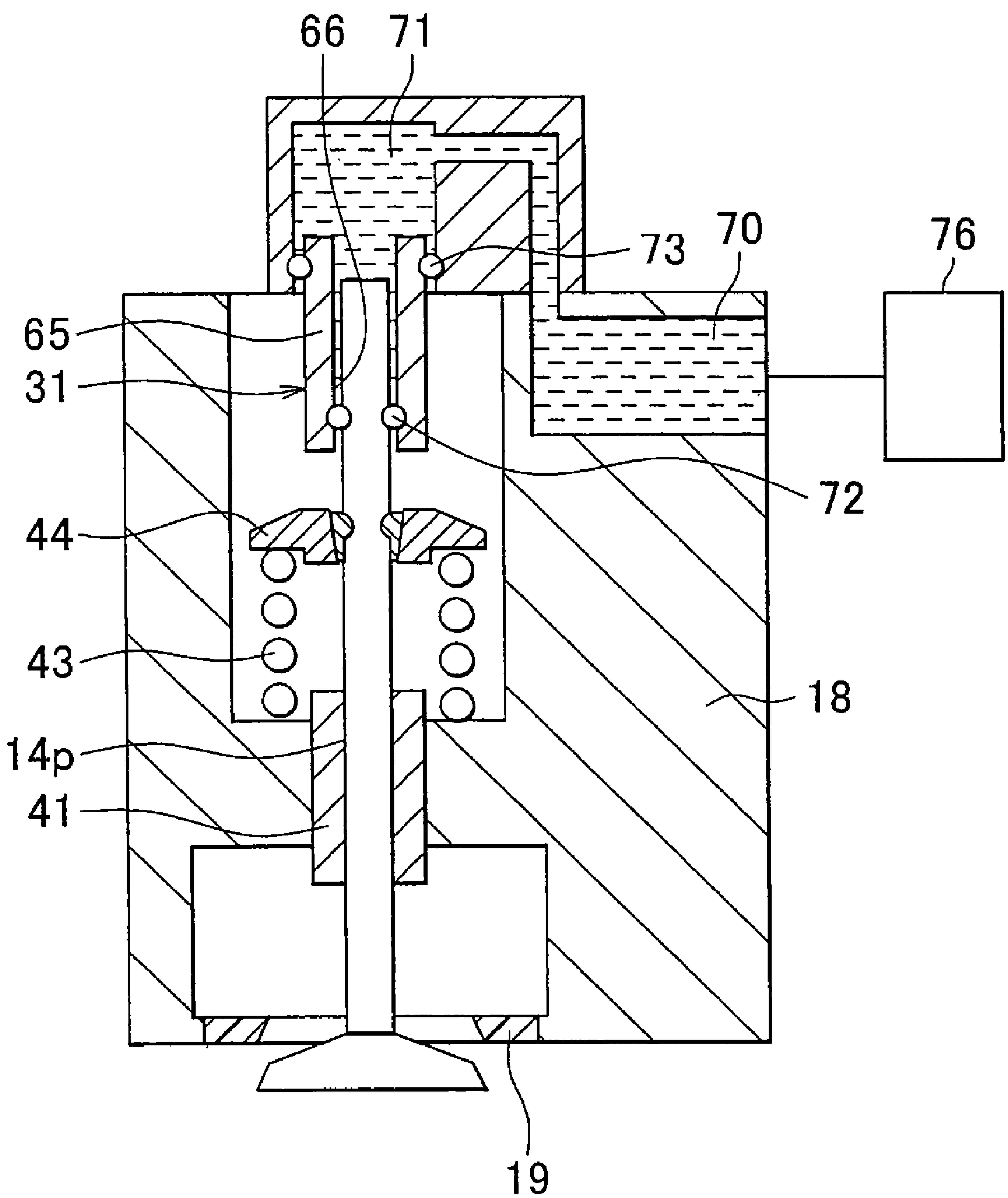

70
72
18
73
71
66
19
65
31
44
43
14p
41

FIG. 9



ELECTROMAGNETICALLY-DRIVEN VALVE

INCORPORATION BY REFERENCE

The disclosure of Japanese Patent Application No. 2007-151528 filed on Jun. 7, 2007 including the specification, drawings and abstract is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to an electromagnetically-driven valve, and more specifically to an electromagnetically-driven valve that collectively opens and closes multiple valves provided in an internal combustion engine.

2. Description of the Related Art

For example, the specification of U.S. Pat. No. 6,467,441 describes art related to an existing electromagnetically-driven valve, more specifically, an electromagnetic actuator that actuates a valve of an internal combustion engine using electromagnetic force and elastic force of a spring in combination. The electromagnetic actuator described in the specification of U.S. Pat. No. 6,467,441 includes a valve that has a stem, and a pivot arm. The pivot arm has a first end portion that is pivotally supported by a support frame, and a second end portion that contacts a tip of the stem. Electromagnets each include a core and a coil wound around the core, and are arranged above and below the pivot arm.

The electromagnetic actuator further includes a torsion bar that is fitted to the first end portion of the pivot arm and that applies force to the valve to open the valve, and a spiral spring that is arranged around the outer periphery of the stem and that applies force to the valve to close the valve. The pivot arm is alternately attracted to the cores of the electromagnets arranged above and below the pivot arm on the basis of the elastic force of the torsion bar and the elastic force of the spiral spring.

Electromagnetically-driven valves that are structured in a fashion similar to that described above are described in Japanese Patent Application Publication No. 2007-23889 (JP-A-2007-23889), Japanese Patent Application Publication No. 2007-32436 (JP-A-2007-32436), the specification of German Patent Laid-Open Publication No. 10025491, the specification of U.S. Pat. No. 7,088,209, the specification of U.S. Pat. No. 6,571,823, and the specification of U.S. Pat. No. 6,481,396.

A structure in which two valves of an engine are collectively driven using the electromagnetically-driven valve described in each of the above documents may be employed. However, when the engine is operating at low speed or low load, a sufficient amount of air may be introduced into the engine or a sufficient amount of exhaust gas may be discharged from the engine by driving only one valve. If two valves are kept driving in such a case, the electromagnetically-driven valve may consume unnecessarily large amount of electric power.

SUMMARY OF THE INVENTION

The invention provides an electromagnetically-driven valve that consumes less amount of electric power.

An aspect of the invention relates to an electromagnetically-driven valve, that includes: a first valve and a second valve that are provided in an internal combustion engine, and that are arranged side by side; a connection member which connects the first valve with the second valve, wherein driving force that is generated by electromagnetic force is transferred to the connection member; and a changing mechanism that is fitted to the connection member. The changing mechanism changes the valve drive state between the first state, in which the first valve and the second valve are both driven, and the second state, in which the first valve is driven and the second valve is stopped.

In the thus structured electromagnetically-driven valve, the drive state of the first valve and the second valve is changed between the first state and the second state based on the operating state of the internal combustion engine. Thus, it is possible to stop the second valve when a proper operation of the internal combustion engine is ensured by driving only the first valve. As a result, the amount of electric power that is consumed by the electromagnetically-driven valve is reduced.

In the first aspect of the invention, the connection member may include a first connection portion that is connected to the first valve and a second connection portion that is connected to the second valve. In addition, the changing mechanism may include an actuator that actuates the connection member. When the changing mechanism changes the valve drive state from the first state to the second state, the actuator may cause the connection member to pivot about the first connection portion to thereby disconnect the second valve from the second connection portion. In the thus structured electromagnetically-driven valve, it is possible to change the valve drive state of the first valve and the second valve between the first state and the second state by actuating the connection member using the actuator.

In the first aspect of the invention, the connection member may include a support portion that movably supports the second valve. In addition, the changing mechanism may include a fixing member that fixes the second valve to the support portion, and an actuator that actuates the fixing member. When the changing mechanism changes the valve drive state from the first state to the second state, the actuator may actuate the fixing member to cancel fixation of the second valve to the support portion by the fixing member to thereby allow the support portion to move relative to the second valve. In the thus structured electromagnetically-driven valve, it is possible to change the valve drive state of the first valve and the second valve between the first state and the second state by actuating the fixing member using the actuator.

In the first aspect of the invention, the connection member may include a support portion that movably supports the second valve. In addition, the changing mechanism may include a hydraulic mechanism that applies hydraulic pressure to the second valve to fix the second valve to the support portion. When the changing mechanism changes the valve drive state from the first state to the second state, fixation of the second valve to the support portion by the hydraulic mechanism may be cancelled to thereby allow the support portion to move relative to the second valve. In the thus structured electromagnetically-driven valve, it is possible to change the valve drive state of the first valve and the second valve between the first state and the second state by applying the hydraulic pressure to the second valve using the hydraulic mechanism or stopping the application of the hydraulic pressure to the second valve.

In the first aspect of the invention, the hydraulic mechanism may include a hydraulic pressure control unit that controls a degree of hydraulic pressure that is applied to the second valve. In the thus structured electromagnetically-driven valve, it is possible to adjust the relative position between the second valve and the connection member by controlling the degree of hydraulic pressure. Thus, it is possible to adjust the distance traveled by the second valve, that is, the valve lift amount.

As described above, the invention provides the electromagnetically-driven valve that consumes less amount of electric power.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and further features and advantages of the invention will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein the same or corresponding portions will be denoted by the same reference numerals and wherein:

FIG. **1** is a plane view showing a gasoline engine that is provided with electromagnetically-driven valves according to a first embodiment of the invention;

FIG. **2** is a cross-sectional view showing the electromagnetically-driven valve according to the first embodiment of the invention;

FIG. **3** is a cross-sectional view showing the electromagnetically-driven valve, taken along the line III-III in FIG. **2**;

FIG. **4** is a cross-sectional view showing an operating state of a valve plate in FIG. **3**;

FIG. **5** is a cross-sectional view showing an electromagnetically-driven valve according to a second embodiment of the invention;

FIGS. **6**A and **6**B are cross-sectional views showing drive states of the electromagnetically-driven valve in FIG. **5**;

FIG. **7** is a cross-sectional view showing an electromagnetically-driven valve according to a third embodiment of the invention;

FIGS. **8**A and **8**B are cross-sectional views showing drive states of the electromagnetically-driven valve in FIG. **7**; and

FIG. **9** is a cross-sectional view showing a modification of the electromagnetically-driven valve in FIG. **7**.

DETAILED DESCRIPTION OF THE EXAMPLE EMBODIMENTS

Hereafter, embodiments of the invention will be described with reference to the accompanying drawings. Note that, the same or corresponding portions will be denoted by the same reference numerals in the drawings.

First Embodiment of the Invention

FIG. **1** is a plane view showing a gasoline engine provided with electromagnetically-driven valves according to a first embodiment of the invention. As shown in FIG. **1**, electromagnetically-driven valves **10** are provided in a gasoline engine **60** that is an internal combustion engine. The gasoline engine **60** includes a plurality of cylinders **200**. The cylinders **200** are aligned in one direction with predetermined intervals. The gasoline engine **60** is an in-line multi-cylinder engine.

The type of an internal combustion engine in which the electromagnetically-driven valve **10** is provided is not particularly limited. For example, the electromagnetically-driven valve **10** may be provided in a diesel engine. The internal combustion engine may be a single-cylinder engine. The layout of the cylinders **200** is not particularly limited. The electromagnetically-driven valve **10** may be provided in, for example, a V engine, a horizontally opposed engine, or a W engine.

Each cylinder of the gasoline engine **60** is provided with intake valves **14***p* and **14***q* and exhaust valves **15***p* and **15***q*. At each cylinder, the intake valve **14***p* and the intake valve **14***q* are arranged side by side, and the exhaust valve **15***p* and the exhaust valve **15***q* are arranged side by side. The electromagnetically-driven valve **10** collectively opens or closes the intake valve **14***p* and the intake valve **14***q* of each cylinder of the gasoline engine **60**. Similarly, the electromagnetically-driven valve **10** collectively opens or closes the exhaust valve **15***p* and the exhaust valve **15***q* of each cylinder of the gasoline engine **60**.

The electromagnetically-driven valve **10** may be structured so as to collectively open or close three or more intake valves or exhaust valves.

FIG. **2** is a cross-sectional view showing the electromagnetically-driven valve according to the first embodiment of the invention. Hereafter, the electromagnetically-driven valve **10** that collectively opens or closes the intake valve **14***p* and the intake valve **14***q* will be described. Note that, the electromagnetically-driven valve **10** that collectively opens or closes the exhaust valve **15***p* and the exhaust valve **15***q* have the same structure.

As shown in FIGS. **1** and **2**, each electromagnetically-driven valve **10** is a pivot-type electromagnetically-driven valve that is driven by combination of electromagnetic force and elastic force. The electromagnetically-driven valve **10** includes the intake valves **14***p* and **14***q*, a disk **21** that pivots about a central axis **25**, which is a virtual axis, and electromagnets **51***m* and **51***n* that apply electromagnetic force to the disk **21**.

The intake valve **14***p* and the intake valve **14***q* include a stem **11***p* and a stem **11***q*, respectively. The stem **11***p* and the stem **11***q* extend in parallel to each other. The intake valve **14***p* and the intake valve **14***q* reciprocate in the direction in which the stems **11***p* and **11***q* extend (direction shown by arrows **101**) in accordance with the pivot motion of the disk **21**.

The intake valves **14***p* and **14***q* are provided in a cylinder head **18**. Intake ports **16** are formed within the cylinder head **18**. Valve seats **19** are provided at positions at which the intake ports **16** are communicated with a combustion chamber **17**. The intake valve **14***p* and the intake valve **14***q* include bell portions **12** that are fitted to the tips of the stem **11***p* and the stem **11***q*. In accordance with the reciprocation of the intake valves **14***p* and **14***q*, the bell portions **12** contact the valve seats **19** or move away from the valve seats **19**, whereby the intake ports **16** close or open.

The electromagnetically-driven valve **10** includes a valve plate **31** and an intermediate stem **32**. The valve plate **31** extends from the intake valve **14***p* toward the intake valve **14***q*. The valve plate **31** connects the intake valve **14***p* and the intake valve **14***q* with each other. The valve plate **31** transfers the driving force generated by the electromagnetic force to the intake valves **14***p* and **14***q*. The intermediate stem **32** connects the disk **21** and the valve plate **31** to each other. The driving force generated by the electromagnetic force is transferred from the disk **21** to the valve plate **31** through the intermediate stem **32**.

The electromagnetically-driven valve **10** includes guide members **41** that guide the stems **11***p* and **11***q* so that the stems **11***p* and **11***q* slide in their axial direction. The electromagnetically-driven valve **10** includes a guide member **42** that guides the intermediate stem **32** so that the intermediate stem **32** slides in its axial direction. The guide members **41** and the guide member **42** are made of metal, for example, stainless, so that these guide members endure high-speed slide over the stems.

Lower springs **43**, which serve as first spring members, are supported on the peripheries of the stems **11***p* and **11***q* by lower retainers **44** having a brimmed shape. The lower springs

43 are formed of coil springs. The lower springs **43** apply elastic forces for moving the stems **11***p* and **11***q* upward to the intake valves **14***p* and **14***q*.

A support base **48** is fixed onto the top face of the cylinder head **18**. The support base **48** supports the electromagnets **51***m* and **51***n*. The electromagnet **51***m* is arranged above the disk **21**, and the electromagnet **51***n* is arranged below the disk **21**.

The electromagnet **51***m* and the electromagnet **51***n* are the same in shape. The shape of the electromagnet **51***n* will be described below. The electromagnet **51***n* includes a coil **53** and a core **52**. The coil **53** is wound around the core **52**.

The core **52** is made of magnetic material. In the first embodiment of the invention, the core **52** is formed of multiple electromagnetic steel plates that are stacked on top of each other. The core **52** may be made of magnetic material other than electromagnetic steel plates, for example, a green compact made of magnetic power. The coil **53** of the electromagnet **51***m* and the coil **53** of the electromagnet **5** in may be made of a continuous single coil wire, or made of separate coil wires.

The support base **48** supports the disk **21**. The disk **21** is made of magnetic material. The disk **21** is formed of a bulk material to maintain a sufficient level of strength. The disk **21** includes a support portion **23** and a connection portion **22**. The central axis **25** is defined in the support portion **23**. The disk **21** extends from the support portion **23** toward the connection portion **22** in the direction that intersects with the stems **11***p* and **11***q*.

A through-hole **24** is formed in the support portion **23**. A torsion bar **30**, which serves as a second spring member, is press-fitted into the through-hole **24**. The torsion bar **30** extends in the axial direction of the central axis **25**. The support portion **23** is pivotally supported by the support base **48** via the torsion bar **30**. When a tip **32***c* of the intermediate stem **32** contacts the connection portion **22**, the intermediate stem **32** and the disk **21** are connected to each other.

The torsion bar **30** applies elastic force for causing the disk **21** to pivot counterclockwise about the central axis **25** to the disk **21**. That is, the torsion bar **30** applies elastic force for moving the stems **11***p* and *l* q downward to the intake valves **14***p* and **14***q* via the valve plate **31**. When the electromagnetic force is not applied to the disk **21**, the disk **21** is kept at the middle portion between the valve-open position and the valve-closed position due to the elastic forces of the lower spring **43** and the torsion bar **30**.

When an electric current is supplied to the coil **53** of the electromagnet **51***m*, a magnetic flux flow is formed so as to pass through the core **52** of the electromagnet **51***m* and the disk **21**. Thus, the electromagnet **51***m* generates electromagnetic force that attracts the disk **21** to the electromagnet **51***m*. When an electric current is supplied to the coil **53** of the electromagnet **5** in, a magnetic flux flow is formed so as to pass through the core **52** of the electromagnet **51***n* and the disk **21**. Thus, the electromagnet **5** in generates electromagnetic force that attracts the disk **21** to the electromagnet **51***n*.

The disk **21** is attracted alternately to the electromagnet **51***m* and the electromagnet **51***n* by the electromagnetic force generated by the electromagnet **51***m* and the elastic force of the lower spring **43**, and the electromagnetic force generated by the electromagnet **51***n* and the elastic force of the torsion bar **30**. As a result, the disk **21** pivots about the central axis **25**. When the disk **21** is attracted to the electromagnet **51***m*, the stems **11***p* and **11***q* move upward, and the intake valves **14***p* and **14***q* are brought to the valve-closed positions. When the disk **21** is attracted to the electromagnet **51***n*, the steps **11***p* and **11***q* move downward, and the intake valves **14***p* and **14***q* are brought to the valve-open positions.

FIG. **3** is a cross-sectional view of the electromagnetically-driven valve, taken along the line III-III in FIG. **2**. FIG. **4** is a cross-sectional view showing an operating state of the valve plate in FIG. **3**.

As shown in FIGS. **2** to **4**, the valve plate **31** includes a connection portion **34**, which serves as a first connection portion, and a connection portion **35**, which serves as a second connection portion. The intake valve **14***p* and the intake valve **14***q* are connected to the connection portion **34** and the connection portion **35**, respectively. A hole **36** and a hole **37** are formed in the connection portion **34** and the connection portion **35**, respectively. The stem **11***p* of the intake valve **14***p* and the stem **11***q* of the intake valve **14***c* are fitted into the hole **36** and the hole **37**, respectively.

A cutout portion **37***g* is formed in the connection portion **35**. The cutout portion **37***g* is formed in such a manner that the periphery of the hole **37** is partially open. The width of the cutout portion **37***g* is larger than the diameter of the stem **11***q*. The entire periphery of the hole **36** is closed.

The electromagnetically-driven valve **10** includes hydraulic cylinders **61** and **62** which serve as actuators. The hydraulic cylinder **61** and the hydraulic cylinder **62** are provided with an arm **61***g* and an arm **62***g*, respectively. The hydraulic cylinder **61** and the hydraulic cylinder **62** are arranged on the respective sides of the valve plate **31**. The arm **61***g* and the arm **62***g* contact the valve plate **31**, at the positions between the connection portion **34** and the connection portion **35**.

The hydraulic cylinders **61** and **62** change the valve drive state between a two-valve drive state in which the intake valve **14***p* and the intake valve **14***q* are both driven, and a one-valve drive state in which the intake valve **14***p* is driven and the intake valve **14***q* is stopped.

More specifically, when hydraulic pressure is supplied to the hydraulic cylinder **61**, the arm **61***g* pushes the valve plate **31**. At this time, the valve plate **31** pivots about the connection portion **34**, whereby the stem **11***q* moves out of the hole **37** through the cutout portion **37**. Thus, the connection portion **35** and the intake valve **14***q* are disconnected from each other. The intake valve **14***q* that is free from the pivot motion of the disk **21** is kept at the valve-closed position due to the elastic force of the coil spring **43**. As a result, the electromagnetically-driven valve **10** is placed in the one-valve drive state in which only the intake valve **14***p* is driven.

When hydraulic pressure is supplied to the hydraulic cylinder **62**, the arm **62***g* pushes the valve plate **31**. At this time, the valve plate **31** pivots in the direction opposite to the direction described above. As a result, the stem **11***q* is fitted into the hole **37** through the cutout portion **37***g*. Thus, the connection portion **35** and the intake valve **14***q* are connected to each other. As a result, the electromagnetically-driven valve **10** is placed in the two-valve drive state in which the intake valve **14***p* and the intake valve **14***q* are both driven.

Note that, devices other than the hydraulic cylinders may be used as the actuators that drive the valve plate **31**. For example, air cylinders or an electric motor may be used as the actuator.

The electromagnetically-driven valve **10** according to the first embodiment of the invention is provided in the gasoline engine **60** which is an internal combustion engine. The electromagnetically-driven valve **10** includes: the intake valve **14***p* and the intake valve **14***q* that are arranged side by side, and that serve as a first valve and a second valve, respectively; the valve plate **31** that connects the intake valve **14***p* and the intake valve **14***q* to each other, and that serves as a connection member to which the driving force generated by the electromagnetic force is transferred; and the hydraulic cylinders **61** and **62**, which serve as changing mechanism, fitted to the valve plate **31**. The hydraulic cylinders **61** and **62** change the valve drive state between the first state in which the intake valve **14***p* and the intake valve **14***q* are both driven and the second state in which the intake valve **14***p* is driven and the intake valve **14***q* is stopped.

With the thus structured electromagnetically-driven valve **10** according to the first embodiment of the invention, a sufficient amount of air is taken in the cylinder by opening one of the intake valve **14***p* and the intake valve **14***q*, for example, when the gasoline engine **60** is operating at low speed or low load. According to the first embodiment of the invention, in such a case, the valve drive state is changed from the two-valve drive state to the one-valve drive state in which only the intake valve **14***p* is driven. Thus, it is possible to minimize the electromagnetic force that is required to drive the valve, thereby reducing the electric power consumed by the electromagnetically-driven valve **10**. In addition, it is possible to make the relative displacement between the valve plate **31** and the intermediate stem **32** substantially equal to zero when the valve is driven, because the changing mechanism is fitted to the valve plate **31**.

Second Embodiment of the Invention

FIG. **5** is a cross-sectional view showing an electromagnetically-driven valve according to a second embodiment of the invention. FIGS. **6**A and **6**B are cross-sectional views showing drive states of the electromagnetically-driven valve in FIG. **5**. The electromagnetically-driven valve according to the second embodiment of the invention has mostly the same structure as that of the electromagnetically-driven valve **10** according to the first embodiment of the invention. The structure common between the first and second embodiments will not be described below.

As shown in FIG. **5** and FIGS. **6**A and **6**B, the valve plate **31** includes a support portion **65**. The support portion **65** movably supports the intake valve **14***q*. The support portion **65** supports the intake valve **14***q* in such a manner that the intake valve **14***q* is allowed to reciprocate. A hole **66** is formed in the support portion **65**. The hole **66** is a through-hole. The stem **11***q* of the intake valve **14***q* is fitted into the hole **66**. The stem **11***q* is fitted into the hole **66** so as to be slidable in the axial direction.

The electromagnetically-driven valve according to the second embodiment of the invention includes a pin **68**, which serves as a fixing member, and a hydraulic cylinder **69**, which serves as an actuator that actuates the pin **68**. For example, the engine oil within the cylinder head **18** is supplied to the hydraulic cylinder **69**.

FIG. **6**A describes the state in which the valve plate **31** is kept at the valve-open position in the two-valve drive state. As shown in FIG. **6**A, when the hydraulic pressure is supplied to the hydraulic cylinder **69**, the pin **68** is fitted into the valve plate **31** and the intake valve **14***q*. Thus, the intake valve **14***q* is fixed to the support portion **65**. At this time, the electromagnetically-driven valve is placed in the two-valve drive state in which the intake valve **14***p* and the intake valve **14***q* are both driven.

FIG. **6**B shows the state in which the valve plate **31** is kept at the valve-open position in the one-valve drive state. As shown in FIG. **6**B, when the supply of hydraulic pressure to the hydraulic cylinder **69** is stopped, the pin **68** moves to the position at which the pin **68** retracts from the valve plate **31** and the intake valve **14***q*. Thus, the fixation of the intake valve **14***q* to the support portion **65** by the pin **68** is cancelled. The intake valve **14***q* is then free from the pivot motion of the disk **21** and stops at the valve-closed position due to the elastic force of the lower spring **43**. The valve plate **31** reciprocates while causing the support portion **65** to slide over the stem **11***q*. As a result, the electromagnetically-driven valve is placed in the one-valve drive state in which only the intake valve **14***p* is driven.

Note that, devices other than the hydraulic cylinders may be used as the actuators that drive the pin **68**. For example, air cylinders or an electric motor may be used as the actuator. The fixing member that fixes the intake valve **14***q* to the support portion **65** is not limited to a pin-shaped member. For example, a friction plate that uses friction engagement to fix the intake valve **14***q* to the support portion **65** may be used as the fixing member.

With the thus structured electromagnetically-driven valve according the second embodiment of the invention, it is possible to produce mostly the same effects as those in the first embodiment of the invention.

Third Embodiment of the Invention

FIG. **7** is a cross-sectional view showing an electromagnetically-driven valve according to a third embodiment of the invention. FIGS. **8**A and **8**B are cross-sectional views showing drive states of the electromagnetically-driven valve in FIG. **7**. The electromagnetically-driven valve according to the third embodiment of the invention has mostly the same structure as that of the electromagnetically-driven valve **10** according to the first embodiment of the invention. The structure common between the first and third embodiments will not be described below.

As shown in FIG. **7**, according to the third embodiment of the invention, the valve plate **31** includes the support portion **65**. The support portion **65** has mostly the same structure as that of the support portion **65** according to the second embodiment of the invention. The electromagnetically-driven valve according to the third embodiment of the invention includes a hydraulic mechanism **70**. The hydraulic mechanism **70** applies hydraulic pressure to the intake valve **14***q* to fix the intake valve **14***q* to the support portion **65**. Namely, the hydraulic pressure that is applied to the intake valve **14***q* by the hydraulic mechanism **70** has a function similar to that of the pin **68** according to the second embodiment of the invention.

The hydraulic mechanism **70** includes a hydraulic chamber **71**. The oil for applying hydraulic pressure to the intake valve **14***q* is supplied to the hydraulic chamber **71**. The support portion **65** is fitted into the hydraulic chamber **71** in such a manner that the support portion **65** slides in the direction in which the valve plate **31** reciprocates. An O-ring **72**, which serves as a seal member, is arranged between the stem **11***q* and the support portion **65**. Similarly, an O-ring **73**, which serves as a seal member, is arranged between the support portion **65** and the inner wall of the hydraulic chamber **71**. With this structure, leakage of oil from the hydraulic chamber **71** is prevented.

FIG. **8**A shows the state in which the valve plate **31** is kept at the valve-open position in the two-valve drive state. As shown in FIG. **8**A, when the hydraulic pressure is applied to the intake valve **14***q* by the hydraulic mechanism **70**, the position of the intake valve **14***q* with respect to the support portion **65** is fixed. The valve plate **31** reciprocates the intake valves **14***p* and **14***q* while sliding over the inner wall of the hydraulic chamber **71**. At this time, the electromagnetically-driven valve is placed in the two-valve drive state in which the intake valve **14***p* and the intake valve **14***q* are both driven.

FIG. **8**B shows the state in which the valve plate **31** is kept at the valve-open position in the one-valve drive state. As shown in FIG. **8**B, when the supply of hydraulic pressure to the hydraulic mechanism **70** is stopped, the intake valve **14***q* is kept at the valve-closed position due to the elastic force of the coil spring **43**. The valve plate **31** reciprocates the intake valve **14***p* while sliding over the inner wall of the hydraulic chamber **71** and the stem **11***q* of the intake valve **14***q*. At this time, the electromagnetically-driven valve is placed in the one-valve drive state in which only the intake valve **14***p* is driven.

With the thus structured electromagnetically-driven valve according to the third embodiment of the invention, it is possible to produce mostly the same effects as those in the first embodiment of the invention.

FIG. **9** is a cross-sectional view showing a modification of the electromagnetically-driven valve in FIG. **7**. FIG. **9** shows the state in which the valve plate **31** is kept at the valve-open position in the two-valve drive state.

As shown in FIG. **9**, in this modification, the hydraulic mechanism **70** includes a hydraulic pressure control unit **76**. The hydraulic pressure control unit **76** controls the degree of hydraulic pressure that is applied to the intake valve **14***q* by the hydraulic mechanism **70**. With this structure, the position at which the intake valve **14***q* is fixed to the support portion **65** may be adjusted, thereby making it possible to change the lift amount of the intake valve **14***q*. For example, as shown in FIG. **9**, the lift amount of the intake valve **14***q* is reduced by setting the degree of hydraulic pressure that is applied to the intake valve **14***q* to a smaller value.

The hydraulic mechanism **70** that includes the hydraulic pressure control unit **76** may be provided to each of the intake valves **14***p* and **14***q*. In this case, it is possible to change the lift amount of the intake valve **14***p* and the lift amount of the intake valve **14***q*, thereby increasing the flexibility of change in the lift amounts.

The structure of an electromagnetically-driven valve to which the invention is applied is not limited to the structures described above. For example, a structure in which an upper disk and a lower disk are arranged above and below an electromagnet, respectively, and an intermediate stem is connected to these disks may be employed. An electromagnetically-driven valve to which the invention is applied is not limited to a pivot type. The invention may be applied to, for example, a translational type electromagnetically-driven valve that drives a valve using a liner motion achieved by electromagnetic force.

Thus, the embodiments of the invention that have been disclosed in the specification are to be considered in all respects as illustrative and not restrictive. The technical scope of the invention is defined by claims, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. An electromagnetically-driven valve, comprising:
- a first valve and a second valve that are provided in an internal combustion engine, and that are arranged side by side;
- a connection member that connects the first valve with the second valve, wherein driving force that is generated by electromagnetic force is transferred to the connection member; and
- a changing mechanism that is fitted to the connection member, and that changes a valve drive state between a first state, in which the first valve and the second valve are both driven, and a second state, in which the first valve is driven and the second valve is stopped,
- wherein, in the second state, relative movement between the connection member and the second valve is allowed so that the driving force that is transferred to the connection member is prevented from being transferred to the second valve.

2. The electromagnetically-driven valve according to claim **1**,

wherein:
- the connection member includes a first connection portion that is connected to the first valve and a second connection portion that is connected to the second valve;
- the changing mechanism includes an actuator that actuates the connection member; and
- when the changing mechanism changes the valve drive state from the first state to the second state, the actuator causes the connection member to pivot about the first connection portion to thereby disconnect the second valve from the second connection portion.

3. The electromagnetically-driven valve according to claim **1**,

wherein:
- the connection member includes a support portion that movably supports the second valve;
- the changing mechanism includes a fixing member that fixes the second valve to the support portion, and an actuator that actuates the fixing member; and
- when the changing mechanism changes the valve drive state from the first state to the second state, the actuator actuates the fixing member to cancel fixation of the second valve to the support portion by the fixing member, to thereby allow the support portion to move relative to the second valve.

4. The electromagnetically-driven valve according to claim **1**,

wherein:
- the connection member includes a support portion that movably supports the second valve;
- the changing mechanism includes a hydraulic mechanism that applies hydraulic pressure to the second valve to fix the second valve to the support portion; and
- when the changing mechanism changes the valve drive state from the first state to the second state, fixation of the second valve to the support portion by the hydraulic mechanism is cancelled to thereby allow the support portion to move relative to the second valve.

5. The electromagnetically-driven valve according to claim **4**, wherein the hydraulic mechanism includes a hydraulic pressure control unit that controls a degree of hydraulic pressure that is applied to the second valve.

6. An electromagnetically-driven valve according to claim **1**, comprising:
- a first valve and a second valve that are provided in an internal combustion engine, and that are arranged side by side;
- a connection member that connects the first valve with the second valve, wherein driving force that is generated by electromagnetic force is transferred to the connection member; and
- a changing mechanism that is fitted to the connection member, and that changes a valve drive state between a first state, in which the first valve and the second valve are both driven, and a second state, in which the first valve is driven and the second valve is stopped,
- wherein both the first valve and the second valve are intake valves or exhaust valves of the internal combustion engine.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,913,655 B2
APPLICATION NO. : 12/155607
DATED : March 29, 2011
INVENTOR(S) : Yutaka Sugie et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column	Line	
5	20	Change "electromagnet **5** in may" to --electromagnet **51***n* may--.
5	42	Change "stems **11***p* and **1** *q*" to --stems **11***p* and **11***q*--.
5	54	Change "electromagnet **5** in," to --electromagnet **51***n*,--.
5	56	Change "electromagnet **5** in" to --electromagnet **51***n*--.
6	15	Change "intake valve **14***c*" to --intake valve **14***q*--.
10	45-46	After "valve" delete "according to claim **1**".

Signed and Sealed this
Sixteenth Day of August, 2011

David J. Kappos
Director of the United States Patent and Trademark Office